THE MARYLAND STORMWATER MANAGEMENT PROGRAM
A NEW APPROACH TO STORMWATER DESIGN

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Maryland's original stormwater management program was developed as part of the Chesapeake Bay Initiatives in 1984. At that time, the prevailing attitude was that controlling flooding caused by increases in new development would maintain the quality of receiving streams. Thus, the original Code of Maryland Regulations (COMAR) specifying stormwater management was slanted towards flood control. Much experience has been gained in years since Maryland implemented the original program.

Recently, additional emphasis has been directed on controlling the quality of runoff from land use changed by urbanization and the quantity of this runoff to reduce stream channel erosion. Recognizing that the State's stormwater management program had not changed in over a decade, the Maryland Department of the Environment (MDE) proposed modifications to the COMAR in July 2000. The primary goals of the proposed regulations were to refocus the overall objectives for controlling runoff from new development and promote environmentally sustainable techniques. To that end, MDE developed the **2000 Maryland Stormwater Design Manual, Volumes I & II** (MDE, 2000) to establish stormwater design criteria and provide specific procedures for local jurisdictional use in improving existing programs for nonpoint source pollution control within the Chesapeake Bay and its tributaries as well as coastal bays. As such, the Design Manual would serve as the primary source of stormwater management information for the development community and regulatory agencies throughout the State.

In the beginning, MDE developed the Design Manual to address three goals to: (1) protect the waters of the State from the adverse impacts urban stormwater, (2) provide design guidance on effective structural and nonstructural best management practices (BMPs) for new development sites, and (3) improve the quality of BMPs that are constructed in the State. While drafting the Design Manual, MDE recognized that the project was evolving into a more comprehensive approach to stormwater design. Included in this approach was better guidance for total site design and incentives for environmentally sustainable or "green" development techniques. The projected outcome of this new approach would be site designs that more closely mimic natural processes and reduce reliance on the use of structural management techniques to treat stormwater runoff.

As a final product, the Design Manual shows great promise in accomplishing the goals and objectives established in the beginning and during this project. The adopted manual serves as a primary source of stormwater design information for the development community and regulatory agencies in both Maryland and in many other areas.

1. Introduction

Maryland's current stormwater management program was established in 1984 when the prevailing attitude was that if the flooding caused by increases in runoff volume from new development was controlled, the quality of receiving streams could be sustained. Hence, the original Code of Maryland Regulations (COMAR) specifying stormwater management design requirements were slanted toward flood control. Specifically, new development was required to reduce post-construction flows of the two and ten-year design storms to pre-development levels. This policy, known as peak management, was thought to address stream channel erosion concerns as well as provide adequate flood control in receiving waters. Although a general definition of water quality management was included in the original regulations, specific guidelines and design criteria were absent from the State's original stormwater management program.

More recently, more emphasis has been placed on controlling the quality of runoff from land use changed by urbanization and the quantity of this runoff to prevent stream channel erosion. Recognizing that Maryland's stormwater management program had not changed since its inception, the Maryland Department of the Environment (MDE) proposed modifications to COMAR in 1993 to refocus the overall objectives of Maryland's efforts toward controlling new development runoff. The goals of these modifications included the control of more frequent storm events, prevention of stream channel erosion, limiting the number of stormwater management waivers, and providing incentives to developers to design projects in an environmentally friendly way. MDE solicited and received an enormous amount of recommendations from numerous organizations and individuals including State and local government officials, developers, design engineers, and environmental groups. While there was general agreement that the State's stormwater management program needed revision, there was a huge disparity in the comments regarding how the program ought to be revised. One common suggestion was that COMAR should set general policy and that specific design requirements should be compiled in a single, separate guidance document. Consequently, MDE commenced work on the development of a stormwater management design manual in 1995.

Maryland's stormwater management program has been considered one of the more advanced of its kind. However, the original program's focus on flood control and its reliance on a preference list for best management practice (BMP) selection hampered MDE's goals to more effectively control nonpoint source pollution, reduce stream channel erosion, and promote innovative stormwater design. The **2000 Maryland Stormwater Design Manual, Volumes I & II** was developed with three distinct goals to; 1) protect the waters of the State from adverse impacts of urban stormwater runoff, 2) provide design guidance on the most effective structural and non-structural BMPs for development sites, and 3) improve the quality of BMPs that are constructed in the State, specifically with respect to their performance, longevity, safety, maintenance, community acceptance, and environmental benefit. On October 2, 2000, the Maryland Department of the Environment (MDE) adopted new stormwater regulations including the Design Manual. Recognizing the demand for environmentally sustainable or "green" design, these regulations represent a more comprehensive approach to stormwater design. Included in this approach are better guidance for total site design and incentives for nonstructural BMPs. The anticipated outcomes of this program are projects designed to more closely mimic natural processes.

While going a long way in promoting sustainable development, the State's stormwater management program is not the only set of rules that govern development. There are several State and local programs (e.g., Critical Areas, Forest Conservation, Wetlands Protection) that promote natural resource conservation. There are also local zoning regulations that govern land development. Although the goal of these diverse programs is to protect the environment, there are instances where green development practices are discouraged and older, less sustainable standards are required.

It is difficult to accommodate the requirements of the full spectrum of resource protection programs. However, the Design Manual recognizes the importance of each and encourages these principles during project design. Accordingly, the State's approach to stormwater design may be summarized as a three-step process: avoidance, minimization, and mitigation. The first step, avoidance, is not just resource protection, but also includes avoiding development practices such as large-scale clearing and mass grading, structural fill, and suburban sprawl that have negative impacts on local hydrology. Any reduction in imperviousness or a site's footprint significantly reduces the amount of stormwater runoff. The second step is minimization. After all options for avoiding impacts are expended, the designer should incorporate practices that either replace or disconnect impervious surfaces. For example, using green roof technology, permeable pavements, or promoting sheet flow will also reduce runoff. After all options to avoid or minimize have been exhausted, the remaining runoff must be treated using structural practices to mitigate water quality and channel stability impacts.

2. The 2000 Maryland Stormwater Design Manual

2.1 Volume I

The first volume of the design manual presents the basic technical information for designing stormwater management in Maryland. Its five chapters present background material on the importance of controlling stormwater runoff, general performance standards for stormwater management, basic stormwater design objectives, minimum design criteria for BMP design, guidance for selecting and locating BMPs, and an innovative system of "credits" for environmentally sensitive design techniques. The information contained in these chapters provides for meeting the three goals of the design manual.

2.1.1 Chapter 1 - Introduction

A basic understanding of the impacts of stormwater runoff on watersheds is critical before any stormwater design criteria can be established. Chapter 1 provides fundamental information on the effects of stormwater runoff on water quality, groundwater recharge, stream channel habitat, overbank flooding, and flood plain expansion. This information is critical if innovative stormwater designs are to be successful.
Chapter 1 also establishes twelve general performance standards for stormwater design and provides guidance on how to use the manual. The chapter concludes with a brief description of new stormwater design requirements and a list of all symbols and acronyms used within the manual.

2.1.2 Chapter 2 – Basic Stormwater Design Criteria

The first goal of the stormwater design manual is to protect the waters of the State from adverse impacts associated with urban runoff. Chapter 2 presents a unified approach to sizing stormwater BMPs for meeting this goal. This approach consists of five criteria (see Table 1) that are designed to meet pollutant removal goals, maintain groundwater recharge, reduce channel erosion, prevent overbank flooding, and pass extreme floods. Of these criteria, the water quality (WQ_v), recharge (Re_v) and channel protection (Cp_v) volumes are determined by soils, amount of imperviousness, proposed design and/or layout, and implementation of nonstructural practices. This simplifies calculations, reduces error and/or abuse, and provides direct incentives to reduce impervious areas.

Another important feature of these three volumetric criteria is the relation to natural hydrologic processes. Explicitly, the Re_v criterion is designed to promote groundwater recharge and interflow. Likewise, the rationale for the Cp_v criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bankful and near bankful events will seldom be exceeded in downstream channels. While the WQ_v is the storage volume needed to capture and treat the runoff from 90% of the average annual rainfall, it also provides management at a critical level (1/3 bankfull elevation) within stream channels. When considered together, these three criteria capture and treat the runoff from at least 95% of the average annual rainfall (see Figure 1) and mimic natural recharge and channel forming processes.

Chapter 2 also introduces five groups of structural BMPs and a group of non-structural BMPs that may be used to meet pollutant removal and groundwater recharge goals. Lastly, this chapter designates certain land uses as "stormwater hotspots" which may restrict the use of certain BMPs and may require pollution prevention plans.

Table 1. Summary of Unified Stormwater Sizing Criteria

Sizing Criteria	Description
Water Quality Volume (WQ_v) (acre-feet)	$WQ_v = [(P)(R_v)(A)]/12$ P = 1.0" in Eastern Zone and 0.9" in Western Zone $R_v = 0.05 + 0.009(I)$ where I is percent impervious cover A = Area in acres
Recharge Volume (Re_v) (acre-feet)	$Re_v = [(S)(R_v)(A)]/12$ S = Soil Specific Recharge Factor Re_v is a sub-volume of WQ_v
Channel Protection Storage Volume (Cp_v)	Cp_v = 24 hour extended-detention of the post-developed one-year 24 hour storm event. Cp_v is not required on the Eastern Shore of Maryland
Overbank Flood Protection Volume (Q_{px})	Local review authorities may require that the peak discharge from the ten-year storm event be controlled to the pre-development rate (Q_{p10}). No control of the two-year storm event (Q_{p2}) is required. For Eastern Shore, provide peak discharge control for the two-year storm event (Q_{p2}). No control of the ten-year storm event (Q_{p10}) is required.
Extreme Flood Volume (Q_f)	Consult with the appropriate local reviewing authority. Normally no control is needed if development is excluded from the 100-year flood plain and downstream conveyance is adequate.

2.1.2.1. Unified Stormwater Sizing Criteria – Water Quality Volume (WQ_v)

The Water Quality Volume (denoted as the WQ_v) is the storage needed to capture and treat the runoff from 90% of the average annual rainfall (COMAR 26.17.02). In numerical terms, it is equivalent to an inch of rainfall multiplied by the volumetric runoff coefficient (R_v) and site area. Treatment of the WQ_v shall be provided at all developments where stormwater management is required. A minimum WQ_v of 0.2 inches per acre shall be met at sites or drainage areas that have less than 15% impervious cover. Drainage areas having no impervious cover and no proposed disturbance during development may be excluded from the WQ_v calculations.

2.1.2.2. Unified Stormwater Sizing Criteria – Recharge Volume Requirements (Re_v)

The criteria for maintaining recharge is based on the average annual recharge rate of the hydrologic soil group(s) present at a site as determined from the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Surveys or from detailed soil investigations. More specifically, each specific recharge factor (*S*) is based on the USDA average annual recharge volume per soil type divided by the annual rainfall in Maryland (42 inches per year) and multiplied by 90% (Table 2). This keeps the recharge volume calculation consistent with the WQ_v methodology.

Table 2. Soil Specific Recharge Factors (*S*)

Hydrologic Soil Group	**USDA Average Annual Recharge Volume***	**Soil Specific Recharge Factor (*S*)**
A	18 inches/year	0.38
B	12 inches/year	0.26
C	6 inches/year	0.13
D	3 inches/year	0.07

*Rawls, Brakensiek & Saxton, 1982

The recharge volume is considered part of the total WQ_v that must be addressed at a site and can be achieved either by nonstructural techniques (e.g., buffers, disconnection of runoff), structural practices (e.g., infiltration, bioretention), or a combination of both. Like WQ_v, drainage areas having no impervious cover and proposed disturbance may be excluded from recharge calculations. Re_v and WQ_v are inclusive. If Re_v is treated upstream of WQ_v, then Re_v may be subtracted from the WQ_v when sizing water quality treatment.

The intent of the recharge requirement is to maintain existing groundwater recharge at development sites. This helps to preserve water table elevations thereby maintaining the hydrology of streams and wetlands

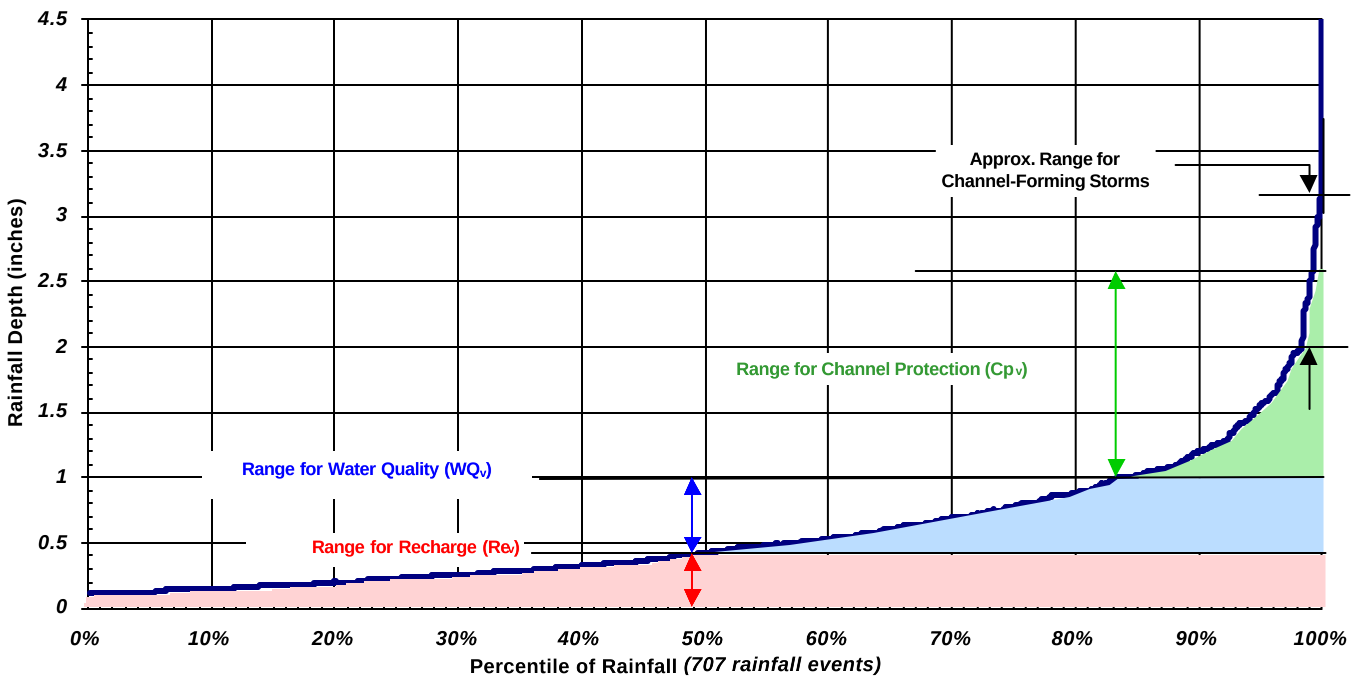

Figure 1. Rainfall events captured and treated by the recharge (Re_v), water quality (WQ_v) and channel protection (Cp_v) volumes using 1980 to 1990 rainfall frequency records for Baltimore City

during dry weather. The volume of recharge that occurs on a site depends on slope, soil type, vegetative cover, precipitation, and evapo-transpiration. Sites with natural ground cover such as forest or meadow have higher recharge rates, less runoff, and greater transpiration losses under most conditions. Because development increases impervious surfaces, a net decrease in recharge is inevitable.

2.1.2.3. Unified Sizing Criteria - Channel Protection Volume (Cp_v)

The primary purpose of the Channel Protection Storage Volume (Cp_v) requirement is to protect stream channels from excessive erosion caused by the increase in runoff from new development. The rationale for this criterion is that runoff from the one year design storm will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will rarely be exceeded in downstream channels. The method for determining the Cp_v requirement is based on the "Design Procedures for Stormwater Management Extended Detention Structures" (MDE, 1987) and is detailed in Appendix D.11 of the Design Manual. The Cp_v requirement does not apply to direct discharges to tidal waters or developments located on Maryland's Eastern Shore.

2.1.3. Chapter 3 – Performance Criteria for Urban BMP Design The secondary and tertiary goals of the design manual are to provide design guidance and improve the quality of BMPs that are constructed in the State. Chapter 3 promotes these goals by outlining performance criteria for five groups of structural stormwater BMPs for water quality treatment (see Figure 2). These performance criteria are designed to ensure that each BMP group is capable of meeting the State's goal of an 80% reduction of total suspended solids (TSS) from urban stormwater runoff. This allows prospective designers to choose from a variety of BMPs that best fit individual site needs and still meet the State's pollutant removal goals. Each set of BMP performance criteria is based on six factors that address general feasibility, conveyance criteria, pretreatment needs, BMP geometry, environmental and landscaping requirements, and maintenance concerns.

Stormwater Ponds
- Micropool Extended-Detention (ED) Ponds
- Wet Ponds
- Wet ED Ponds
- Multiple Pond Systems
- "Pocket " Ponds

Stormwater Wetlands
- Shallow Wetland
- ED Shallow Wetland
- Pond/Wetland System
- "Pocket" Wetland

Stormwater Infiltration
- Infiltration Trench
- Infiltration Basin

Stormwater Filtering Systems
- Surface Sand Filters
- Underground Sand Filters
- Perimeter Sand Filters
- Organic Filters
- Pocket Sand Filters
- Bioretention

Open Channel Systems
- Dry Swale
- Wet Swale

Figure 2. Structural BMPs that may be used for "stand alone" water quality treatment in Maryland

2.1.3. Chapter 4 –Selecting and Locating the Most Effective BMP System

In conjunction with the previous chapter, Chapter 4 promotes the secondary and tertiary goals of the manual by outlining a process for selecting the best BMP or group of BMPs for a development site. The chapter also provides guidance on factors to consider when locating BMPs at a given site. This process is used to filter those BMPs that can meet the pollutant removal targets for WQ_v and guides designers through six steps that screen for watershed factors, terrain factors, stormwater treatment suitability, physical feasibility factors, community and environmental factors, and locational / permitting factors. These factors, when used progressively, allow designers to select BMPs that are most suitable for the various physiographic regions within the State as well as for specific site and design characteristics such as land use or wildlife habitat enhancement.

2.1.5. Chapter 5 – Stormwater Credits

One of the major programmatic changes promoted by the Design Manual is the notion that stormwater management should not rely solely on the use of structural BMPs but should integrate stormwater into the overall site design process. Chapter 5 supports this philosophical change by advancing a series of nonstructural design practices that can reduce the generation runoff from a site thereby reducing the size and cost of structural BMPs. Additionally, these practices provide partial removal of many pollutants. To promote greater use, these non-structural practices have been classified into six sub-groups (see Table 3.) with an associated "credit" provided for designers utilizing these progressive techniques.

Table 3. Stormwater Credits for Innovative Site Design

Stormwater Credit	Description
Natural Area Conservation	Conservation of natural areas such as forest, non-tidal wetlands, or other sensitive areas in a protected easement thereby retaining their pre-development hydrologic and water quality characteristics. Using this credit, a designer may subtract conservation areas from total site area when computing WQ_v. Additionally, the post-development curve number (CN) for these areas may be assumed to be forest in good condition.
Disconnection of Rooftop Runoff	Credit is given when rooftop runoff is disconnected and then directed over a pervious area where it may either infiltrate into the soil or filter over it. Credit is typically obtained by grading the site to promote overland flow or by providing bioretention on single-family residential lots. If a rooftop area is adequately disconnected, the impervious area may be deducted from the total impervious cover. Additionally, the post-development CNs for disconnected rooftop areas may be assumed to be forest in good condition.
Disconnection of Non-Rooftop Runoff.	Credit is given for practices that disconnect surface impervious cover by directing it to pervious areas where it is either infiltrated or filtered though the soil. As with rooftop runoff, the impervious area may be deducted from the total impervious cover thereby reducing the required WQ_v.
Stream Buffer Credit	Credit is given when a stream buffer effectively treats stormwater runoff. Effective treatment constitutes capturing runoff from pervious and impervious areas adjacent to the buffer and treating the runoff through overland flow across a grass or forested area. Areas treated in this manner may be deducted from total site area in calculating WQ_v and may contribute to meeting requirements for groundwater recharge.
Grass Channel (Open Section Roads)	Credit may be given when open grass channels are used to reduce the volume of runoff and pollutants during smaller storms. Use of grass channels will automatically meet the minimum groundwater recharge requirement. If designed according to listed criteria, these channels may meet water quality criteria for certain types of residential development.
Environmentally Sensitive Rural Development	Credit is given when a group of environmental site design techniques are applied to low density or rural residential development. This credit eliminates the need for structural practices to treat both Re_v and WQ_v. The designer must still address Cp_v and Q_{px} requirements for all roadway and connected impervious surfaces.

2.2 Volume II – Technical Appendices

The second volume of the design manual was crafted to support the technical requirements of the first without duplicating information that is readily available from other resources. This paring of support information was necessary to prevent the design manual from becoming unusable because of repetitive information. The decision to include information in this volume was based primarily on availability in existing documents, or the relevance to information within Volume I. After sifting through the massive amount of support information related to stormwater design, four appendices were drafted that contain the minimum information required for the design manual to be self sufficient yet not overly large. These appendices contain information such as landscaping guidance (App. A) and BMP construction specifications (App. B.), as well as step-by-step design examples for each structural BMP group (App. C) and an assortment of tools (App. D) that assist in the design of various stormwater systems. This collection of information is either unavailable in outside sources or intrinsically valuable to the proper design of stormwater management.

3. Conclusions

The Environment Article Title 4, Subtitle 2, Annotated Code of Maryland states that "...the management of stormwater runoff is necessary to reduce stream channel erosion, pollution, siltation and sedimentation, and local flooding, all of which have adverse impacts on the water and land resources of Maryland." The program designed in the early 1980's to address this finding of the General Assembly concentrated primarily on controlling runoff increases associated with new development. Over the last 18 years, tens of thousands of BMPs have been constructed in order to curb flooding caused by urbanization. Although implementation has not changed, our stormwater management knowledge and experience has continued to evolve since Maryland enacted its stormwater statute. With the experience gained comes the identification of improvements that are needed to fulfill the original intent of this essential water pollution control program.

Conventional development and construction processes are increasingly identified as destructive to the environment, encroaching upon natural areas such as wetlands, stream systems, and forests. These activities also alter local hydrology. Trees and meadow grasses that intercept and absorb rainfall are removed and natural depressions that temporarily pond water are graded to a uniform slope. Cleared and graded sites are often compacted, contributing to the rapid conversion of rainfall into runoff. Impervious surfaces impede groundwater recharge. Pollutants accumulated on these surfaces quickly wash off and are delivered to receiving waters. While stormwater runoff from developed areas adversely impacts water quality, channel stability, and disrupts aquatic life, using environmentally sustainable site design techniques may reduce these impacts.

On October 2, 2000, the Maryland Department of the Environment (MDE) adopted stormwater regulations including the **2000 Maryland Stormwater Design Manual, Vol. I & II** (the Design Manual). Recognizing the demand for environmentally sustainable or "green" development, these regulations represent a more comprehensive approach to stormwater design. Included in this approach are better guidance for total site design and incentives for nonstructural BMPs. The projected outcome of this new program is hoped to be designs that more closely mimic existing hydrology.

While going a long way in promoting sustainable development, the State's stormwater management program is not the only set of rules that govern development. There are several State and local programs (e.g., Critical Areas, Forest Conservation, Wetlands Protection) that promote natural resource conservation. There is also the local zoning regulations that govern land development. Although the goal of these diverse programs is to protect the environment, there are instances where green development practices are discouraged and older, less sustainable standards are required.

It is difficult to accommodate the requirements of the full spectrum of resource protection programs. However, the Design Manual recognizes the importance of each and encourages these principles during project design. Accordingly, the State's approach to stormwater design may be summarized as a three-step process: avoidance, minimization, and mitigation. The first step, avoidance, is not just resource protection, but also includes avoiding development practices such as large-scale clearing and mass grading, structural fill, and suburban sprawl that have negative impacts on local hydrology. Any reduction in imperviousness or a site's footprint significantly reduces the amount of stormwater runoff. The second step is minimization. After all options for avoiding impacts are expended, the designer should incorporate practices that either replace or disconnect impervious surfaces. For example, using green roof technology, permeable pavements, or promoting sheet flow will also reduce runoff. After all options to avoid or minimize have been exhausted, the remaining runoff must be treated using structural practices to mitigate water quality and channel stability impacts.

Maryland's stormwater management program is one of many State and local programs that regulate land development. However, the three-step philosophy inherent in the Design Manual incorporates many of these other programs in its approach. This philosophy refocuses design from the structural management of runoff as an afterthought to the mimicking of natural processes as part of a total site design.

The Design Manual could never have been produced without the talents, experience, and hard work of the many people involved in the project. The Maryland Department of the Environment, Water Management Administration would like to acknowledge those individuals who helped in this process. In particular, Tom Schueler, Richard Claytor and the staff of the Center for Watershed Protection as well as their project team partners, Environmental Quality Resources, Inc. and Loiederman Associates, Inc. for their dedication and efforts. Thanks are also extended to the members of the Stormwater Management Regulations Committee whose insightful comments and local perspective were helpful in improving the manual. Finally, the staff of MDE/WMA's Nonpoint Source Program for the patience and support necessary to complete the project successfully.

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